(12) UK Patent Application (19) GB (11) 2 035 599 A

(21) Application No 7938061
(22) Date of filing 2 Nov 1979
(30) Priority data
(31) 78/43166
(32) 3 Nov 1978
(33) United Kingdom (GB)
(43) Application published
18 Jun 1980
(51) INT CL³
G02B 5/16
(52) Dom stic classification
G2J GC
(56) Documents cited
GB 1501777
GB 1488528
GB 1488058
GB 1487464
GB 1471098
GB 1422956
(58) Field of search
G2J
(71) Applicants
Associated Electrical Industri s Limited, 1 Stanhope Gate, London
(72) Inventors
Dennis Laurence Lewis
Colin Joseph Peachey
Rex Francis Williams
(74) Agent
H. V. A. Kirby

(54) **Electric power cables incorporating optical transmission elements**

(57) In an electric power cable including a plurality of insulated conducting cores and one or more optical transmission elements, each optical transmission element consists of one or more optical fibre waveguide units 56 helically coiled around a mandrel 57 which may be an additional insulated conducting core. Each optical fibre unit consists of a single optical fibre with a protective resin coating and containined within a tube 58 of high tensile modulus polymeric material such as amorphous nylon, polyester, or a fluoropolymer, the tube being either loosely fitting around a coated fibre, or tightly fitting over a buffer coated fibre.

Optical transmission elements of this form are especially suitable for power cables designed for use in arduous environments, such as mine trailing cables, the helical winding of the fibre units allowing the cable to be strained to a considerable extent without the fibres being subjected to strain. Several mine cable constructions are described.

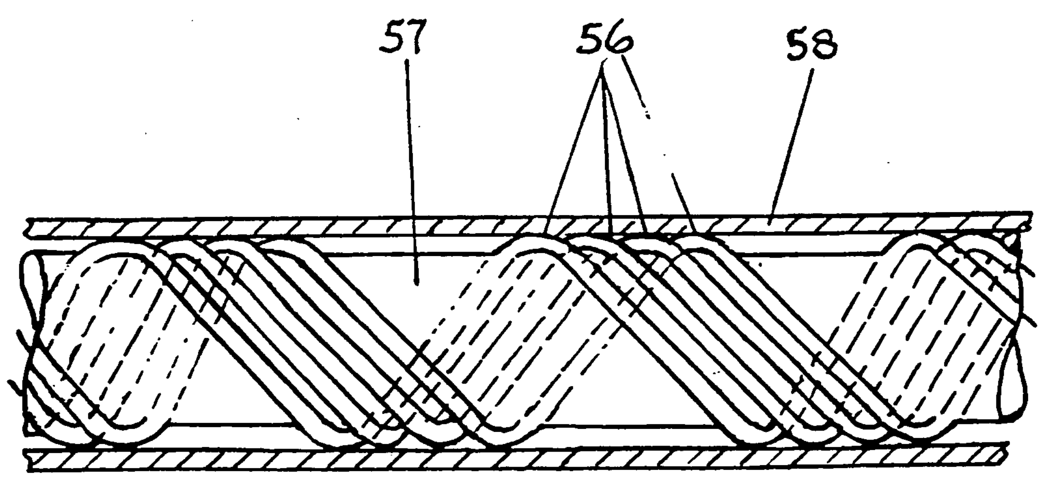

FIG.5.

POOR QUALITY

GB 2 035 599 A

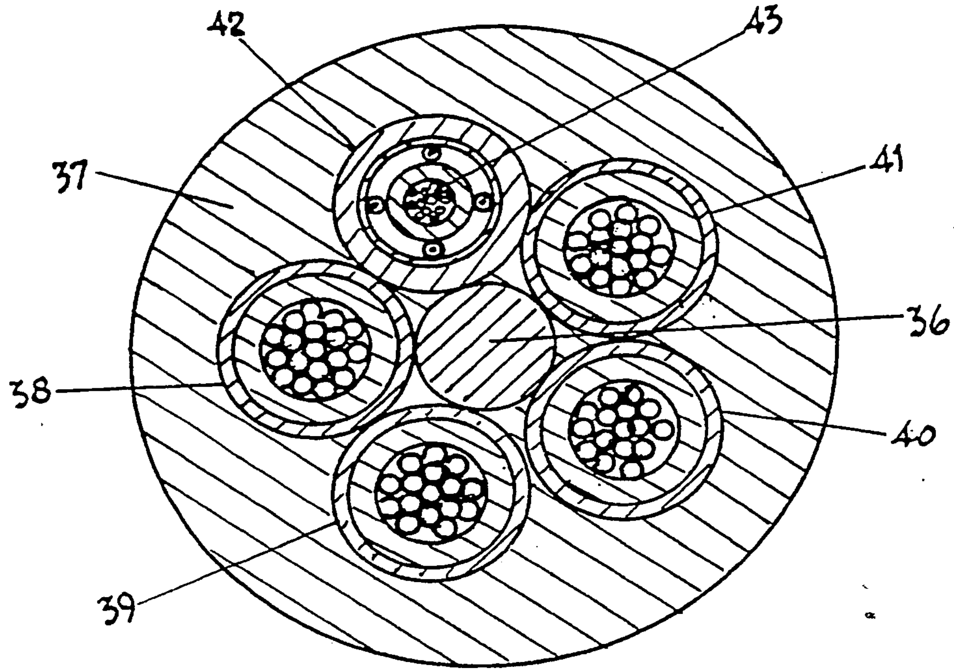

FIG. 3.

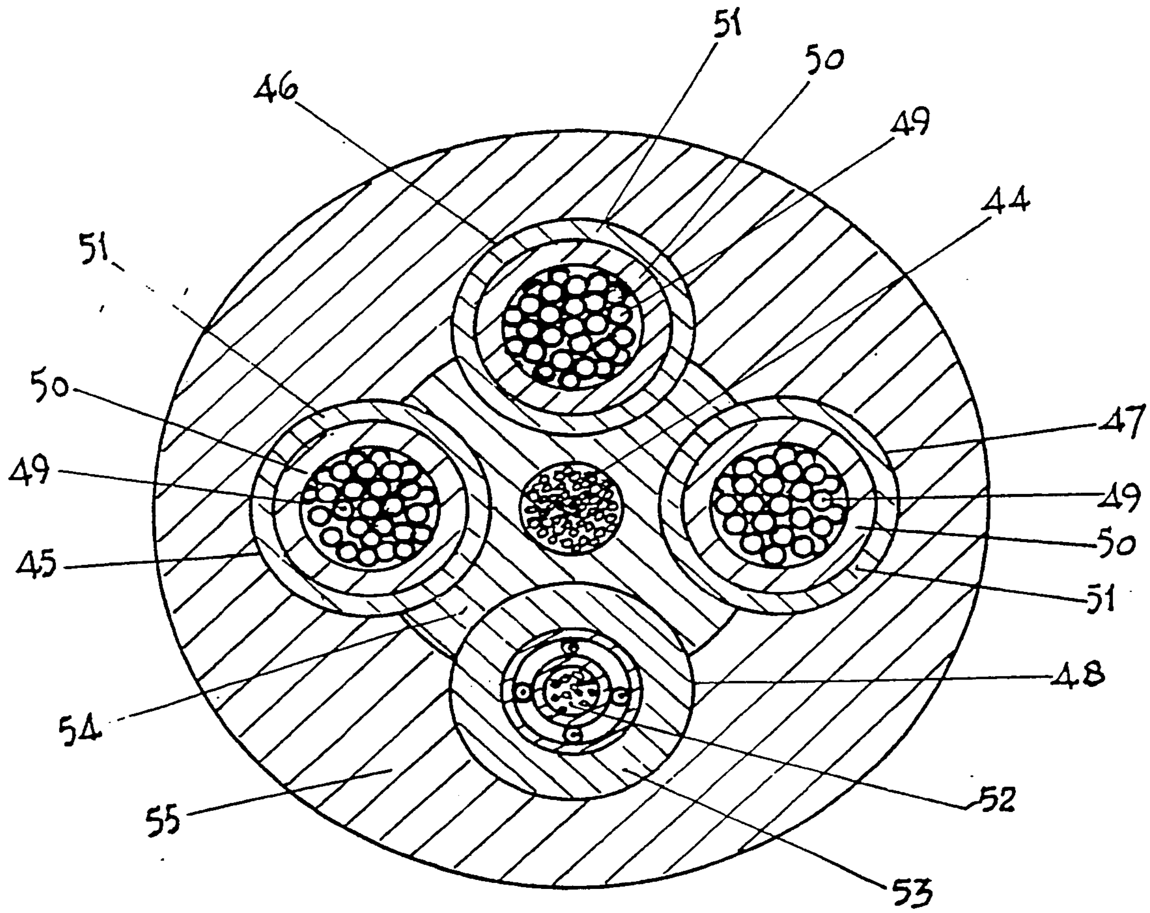

FIG. 4.

ORIGINAL INSPECTED

SPECIFICATION

Electric power cables incorporating optical transmission elements

This invention relates to cables of the type incorporating, within a common sheath, electrical conductors for the transmission of electrical power, and one or more optical fibre waveguides for the transmission of communication signals.

The invention is especially, but not exculsively, concerned with the incorporation of optical communication links in electric power cables designed for use in arduous environments in which they are liable to be subjected to a considerable amount of stress and/or movement, for example trailing cables such as those employed in coal mines for supplying power to the cutters at the coal face. Cables employed under such conditions are liable to undergo considerable strain, and damage in the form of crushing and tearing of the cable sheath, and trailing ables are required to possess a high degree of flexibility as well as being sufficiently robust to withstand such strain. When it is desired to incorporate optical fibre waveguides in such a cable, problems arise not only in protecting the fibres from mechanical damage, but also in ensuring that they will not be subjected to a degree of strain which would appreciably increase the optical attenuation in operation of the waveguides.

It is an object of the present invention to provide a cable incorporating electrical power conductors and one or more optical fibre waveguides, which cable is so constructed that under conditions of use involving stretching, flexing, and possibly crushing of the cable, the optical fibre or fibres will be protected against damage and will undergo little or no strain.

According to the invention, in an electric power cable including a plurality of electrical conductor elements and at least one optical transmission element, all of which elements are surrounded by or embedded in a common sheath of elastomeric material, the optical transmission element, or each optical transmission element, consists of one or more optical fibre waveguide units helically coiled around a mandrel, with means for holding said unit or units in position on the mandrel, each said unit being composed of a single optical fibre having an adherent protective coating of synthetic polymeric material and contained within an outer tube formed of synthetic polymeric material having a high tensile modulus such that the tube is resistant to crushing and stretching.

An "electrical conductor element", as referred to herein, consists of an electrically conducting core, preferably of stranded form, surrounded by a closely fitting jacket composed of a layer of insulating material and any additional layer or layers which may be required, such as metal-containing earth screening layer in the case of a power core, and/or a layer of elastomeric material to build up the element to the require overall diameter. If desired, an additional insulated stranded conducting core may be incorporated in an optical transmission element, or in each optical transmission element, forming the mandrel on which the optical fibre unit or units is or are wound. Each optical transmission element may also, if required, be surrounded by an elastomeric build-up layer.

An optical transmission element may be located along the axial region of the cable, or may be included with conductor elements arranged around a central member, or optical transmission elements may be located in both of such positions in a single cable. In the preferred cable construction a plurality of conductor elements, with or without one or more optical transmission elements, are helically twisted around a member disposed along the axial region of the cable, which member may be a conductor, with or without a jacket as aforesaid, or an optical transmission element, or an elastomeric body. The helical arrangement of the elements around the axial member promotes flexibility of the cable while reducing strain in use. These effects are enhanced if, as is preferred, each of the conducting cores is composed of a helically stranded assembly of wires.

The interstices between the elements are preferably filled either with the material of the cable sheath or with suitable packing material, preferably elastomeric, to form a robust, crush-resistant structure. In some cases, a semiconducting elastomer, for example carbon-loaded rubber, may be employed as at least part of the interstitial material, and/or as an outer layer of the jackets of the elements, in substitution for a metallic screening layer or as a build-up layer. The elastomeric materials employed in the construction of the cable, for forming the cable sheath, jackets and build-up layers of the elements, packing material, and axial elastomeric body if required, are preferably vulcanised natural or synthetic rubbers.

In each optical fibre waveguide unit, the protective coating on the optical fibre may consist of a relatively hard synthetic polymeric material, for example polyurethane resin, preferably containing a filler such as carbon powder, and a fibre so coated may be loosely disposed within an extruded outer tube. The term "loosely", in this context, is to be understood to mean that the bore of the tube is of sufficiently large cross-section to permit freedom of movement of the coated fibre within it in both radial and axial directions: such loose containment of the fibre is advantageous in that it reduces optical losses, due to microbending, in operation of the waveguide. If desired, the outer tube may be filled with fluid, preferably a thixotropic fluid, which in the unstressed, viscous state acts as a cushion minimising the effect on the fibre of any external forces applied to the tube, and which in the condition of reduced viscosity resulting from applied stress permits rapid movement of the fibre within the fluid to take up a position of minimum strain within the tube. Also if desired, the tube may be reinforced with elongate strength members, for example composed of steel wire, silica fibres, or aromatic polyamide yarns, embedded in the tube walls.

In an alternative form of optical fibre waveguide unit, suitable for use in the cable of the invention, the protective coating on the optical fibre consists of or includes a buffer coat of a relatively soft polymeric

fibre unit or units in position on the mandrel, so that the unit or units will not be dislodged or distorted during the extrusion of an elastomeric build-up layer or the cable sheath around the optical transmission element. Such holding means may consist, for example, of an adhesive, or a helical groove in the mandrel surface, or a covering sleeve formed either by winding a suitable tape around the element or by extruding a tube of elastomeric material over the element. If a tape sleeve is used it should not be so tightly wound as to retrain the optical fibre unit or units too firmly to permit elongation of the tube helix or helices.

Some specific forms of cable in accordance with the invention will now be described by way of example, with reference to the accompanying diagrammatic drawings, in which

Figures 1, 2, 3 and 4 respectively show, in cross-section, different forms of trailing cable for use in coal mines, and

Figure 5 is a longitudinal part-sectional view of a portion of an optical transmission element of the form incorporated in any of the cables of Figures 1 to 4.

The cable shown in Figure 1 includes three electrical conductor elements 1, 2, 3 and an optical transmission element 4 incorporating a further electrical conductor, these four elements being helically twisted around a bundle of wires 5 which constitutes an earth conductor and is disposed along the axial region of the cable. The structure so formed is encased in a sheath 6 of elastomeric material. Each of the elements 1, 2 and 3 consists of a power core 7 composed of a helically twisted assembly of a plurality of helically inter-twisted bundles of wires, covered by an inner layer 8 of elastomeric insulating material and an outer layer 9 of braid incorporating wire strands to form an earth screen. The optical transmission element 4 includes four optical fibre units each consisting of a single resin-coated optical fibre 10 loosely disposed in a tube 11 of nylon having a tensile modulus of 2.8 giga pascals; these units are helically coiled around a mandrel consisting of a pilot core 12 formed of helically twisted bundles of wires, with a covering layer 13 of elastomeric insulating material: the pilot core is of the same construction as, but of smaller diameter than, the power cores 7. The optical fibre units are convered by a sleeve 14, which may be a winding of tape formed of resin-impregnated textile fabric or of polyester sheet, or may be an extruded tube of elastomeric material, and the sleeve is covered by a further layer 15 of elastomeric material, to build up the element to a diameter equal to that of the elements 1, 2 and 3.

In a specific example of a cable of the form shown in Figure 1, the cores 7 and 12 and the earth conductor 5 are all composed of fine tinned copper wires, the insulating layers 8 and 13 consist of ethylene-propylene rubber or chloro-sulphonated polyethylene, the build-up layer 15 and the sheath 6 consist of polychloroprene, and the braid forming layers 9 is composed of tinned copper wires and nylon filaments, all the elastomeric materials being vulcanised.

In the cable shown in Figure 2, an optical transmission element 16 is disposed along the axial region of the cable and is surrounded by a helically inter-twisted assembly of five electrical conductor elements 17 to 21 inclusive, the whole structure being embedded in an elastomeric sheath 22. Each of the elements 17, 18 and 19 consists of a power core 23 covered by a layer 24 of elastomeric insulation, and braid 25 incorporating a metallic earth screen. The element 20 consists of a pilot core 26 covered by a layer 27 of elastomeric insulation and a further build-up layer 28 of elastomeric material. The element 21 consists of an earth core 29 covered by an elastomeric insulating layer 30 and an elastomeric build-up layer 31. The cores of all these elements are composed of wires, for example of tinned copper, and are of similar construction to the conducting cores described above with reference to Figure 1; the insulating layers, build-up layers, braid and sheath may be composed of the same materials as the corresponding layers described in the above specific example with reference to Figure 1.

The optical transmission element 16 of Figure 2 includes four optical fibre units 32 of the form described with reference to Figure 1, helically coiled around a mandrel 33, which may be formed wholly of elastomeric material or may incorporate a conducting core if desired, and covered by a sleeve 34 formed of resin-impregnated fabric tape, polyester tape, or an extruded tube of elastomeric material. The interstices between the said sleeve and the electrical conductor elements 17 to 21 are filled with suitable packing material 35, which is preferably elastomeric.

The cable shown in Figure 3 again consists of five elements helically twisted around an axial member 36, which is suitably formed of a natural or synthetic rubber or may, if desired, be an additional insulated conductor core, the whole structure being embedded in an elastomeric sheath 37. The intertwisted elements consist of three insulated power cores 38, 39, 40, of the same construction as the elements 17, 18 and 19 in Figure 2, an insulated earth core 41 of the same construction as the element 21 in Figure 2, and an optical transmission element 42 of the same construction as the element 4 in Figure 1, incorporating an insulated pilot core 43 as the mandrel. The materials of the core covering layers and the sheath may be the same as those described with reference to Figure 1, and all the cores are formed of intertwisted assemblies of tinned copper wires.

The cable shown in Figure 4 comprises an axially disposed earth conductor 44, surrounded by a helically twisted assembly of three electrical conductor elements 45, 46, 47 and an optical transmission element 48. Each of the elements 45, 46 and 47 consists of a power core 49 jacketed with a layer 50 of elastomeric insulation, suitably ethylene-propylene rubber of chloro-sulphonated polyethylene, and an outer layer 51 of semiconducting elastomer. The optical transmission element 48 is of similar construction to that of the element 4 of Figure 1, the mandrel being an insulated pilot core 52, but the element has an outer covering layer 53 of semiconducting elastomer. The elements 45, 46, 47 and 48 are partially embedded in a semiconducting cradle

resin-coated optical fibre loosely (as hereinbefore defined) disposed in an extruded outer tube.

8. A cable according to Claim 7, wherein the said outer tube of each optical fibre unit is filled with a thixotropic fluid.

9. A cable according to any of the preceding Claims 1 to 6, wherein the protective coating on the optical fibre in each said optical fibre unit consists of or includes a buffer coat of silicone resin, and the said outer tube of each said unit is a tightly fitting jacket extruded over the said protective coating.

10. A cable according to any preceding Claim, wherein the said outer tube of each optical fibre unit is composed of amorphous nylon, or of a melt-processable polyester, or of a fluoropolymer.

11. A cable according to any preceding Claim, which includes a said optical transmission element wherein the mandrel is composed of stranded wires.

12. A cable according to any preceding Claim, which includes a said optical transmission element wherein the mandrel consists of an insulated -anded conducting core.

13. A cable according to any preceding Claim, which includes a said optical transmission element wherein the mandrel is composed of non-metallic material which is flexible and capable of elongation.

14. A cable according to any preceding Claim, wherein the said means for holding the said optical fibre unit or units in position on the mandrel is an adhesive.

15. A cable according to any of the preceding Claims 1 to 13, wherein the said means for holding the optical fibre unit or units in position on the mandrel consists of a helical groove or grooves in the mandrel surface.

16. A cable according to any of the preceding Claims 1 to 13, wherein the said means for holding the optical fibre unit or units in position on the mandrel is a sleeve composed of a winding of tape or an extruded tube of elastomeric material.

17. A cable according to Claim 1, substantially as shown in, and as hereinbefore described with reference to, any one of Figures 1, 2, 3 and 4 of the accompanying drawings, incorporating an optical transmission element substantially as shown in and hereinbefore described with reference to Figure 5 of the said drawings.

18. A cable according to Claim 17, with the modification that, in each optical fibre unit of the optical transmission element, the said tube in which the resin-coated optical fibre is loosely dispersed in filled with a thixotropic fluid consisting of a colloidal suspension of silica powder in silicone oil.

19. A cable according to Claim 17, with the modification that each optical fibre unit in the optical transmission element consists of a silica-based optical fibre having an adherent buffer coat of silicone resin from 30 to 60 microns thick, and a tightly fitting outer jacket of polyester resin extruded over the said buffer coat.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1980.
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.